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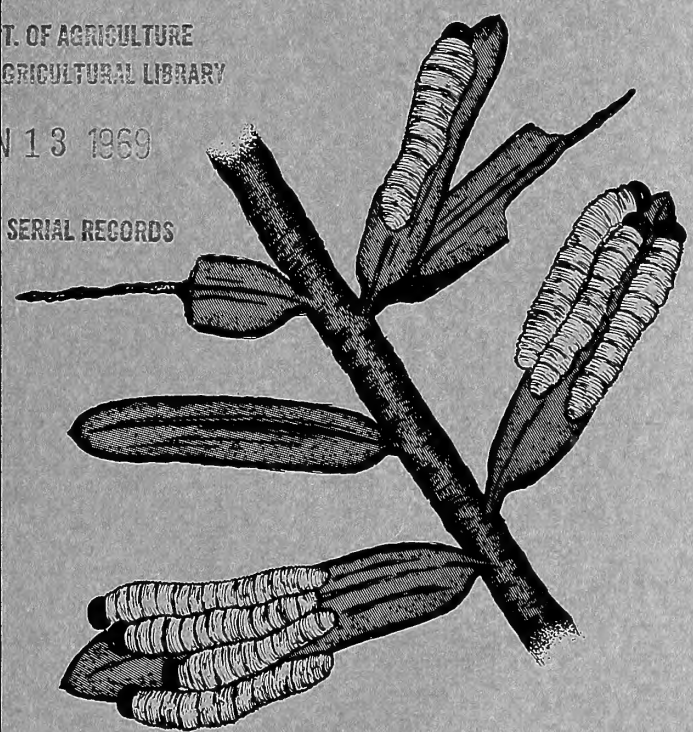
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# THE HEMLOCK SAWFLY IN SOUTHEAST ALASKA

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**INSTITUTE OF NORTHERN FORESTRY**  
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## CONTENTS

	<u>Page</u>
INTRODUCTION. . . . .	1
TAXONOMY. . . . .	1
STUDY AREAS . . . . .	1
DISTRIBUTION AND HOSTS . . . . .	1
LIFE HISTORY . . . . .	1
LARVAL SEXING . . . . .	5
LARVAL FEEDING . . . . .	5
COCOON SIZE RELATED TO SEX. . . . .	7
FECUNDITY . . . . .	7
OVIPOSITION HABITS AND EGG DISTRIBUTION . . . . .	9
NATURAL CONTROL . . . . .	10
Parasites . . . . .	10
Diseases. . . . .	10
Other . . . . .	10
SUMMARY . . . . .	10

mists have all been identified as *Neodiprion tsugae*.

## STUDY AREAS

Sawfly populations were studied in tidewater western hemlock-Sitka spruce stands at Limestone Inlet and Taku Harbor on the mainland, and on Chichagof Island at Todd (fig. 1). Populations at Sitkoh, Trap, Crab, and Freshwater Bays on Chichagof Island were also sampled to determine the species and relative importance of sawfly parasites.

## INTRODUCTION

The hemlock sawfly, *Neodiprion tsugae* Midd., is a primary defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., in southeast Alaska. Sawfly outbreaks have occurred with black-headed budworm, *Acleris variana* (Fern.), outbreaks resulting in defoliation of large acreages of western hemlock. A general collapse of black-headed budworm populations in 1965 throughout southeast Alaska left almost pure sawfly populations available for study. Since then, the sawfly has defoliated many acres of western hemlock, and heavily defoliated areas show some evidence of top-kill.

## TAXONOMY

The hemlock sawfly was described by Middleton in 1933.<sup>1/</sup> Although it has been confused with closely related sawflies in some portions of its range, no related species are known to occur in Alaska in appreciable numbers. Sawfly larval and pupal collections sent to taxono-

## DISTRIBUTION AND HOSTS

The sawfly occurs throughout the range of its host, western hemlock, in southeast Alaska. Other species which may be defoliated are mountain hemlock, *Tsuga mertensiana* (Bong.) Carr.; Pacific silver fir, *Abies amabilis* (Dougl.) Forbes; and Sitka spruce, *Picea sitchensis* (Bong.) Carr. Whether sawfly females will oviposit on the latter three species is unknown.

## LIFE HISTORY

Hemlock sawflies overwinter in the egg stage (fig. 2A). Eggs hatch in early June, and the larvae feed gregariously on old foliage (fig. 2B). As larvae mature, they disperse and feed singly. New foliage is fed on in the absence of old foliage. Larvae complete development in late July and spin cocoons (fig. 2C) on the foliage and in the litter beneath host trees. Cocoons spun on the host foliage are found most frequently in the lower tree crowns. Adult sawflies (fig. 2D) emerge from August through October, with males normally emerging earlier than females. The earliest record of cocoons in the field was July 12. Adults were observed in the field as late as October 15.

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<sup>1/</sup> Middleton, William. Five new sawflies of the genus *Neodiprion* Rohwer. Can. Entomol. 65(4): 77-79. 1933.



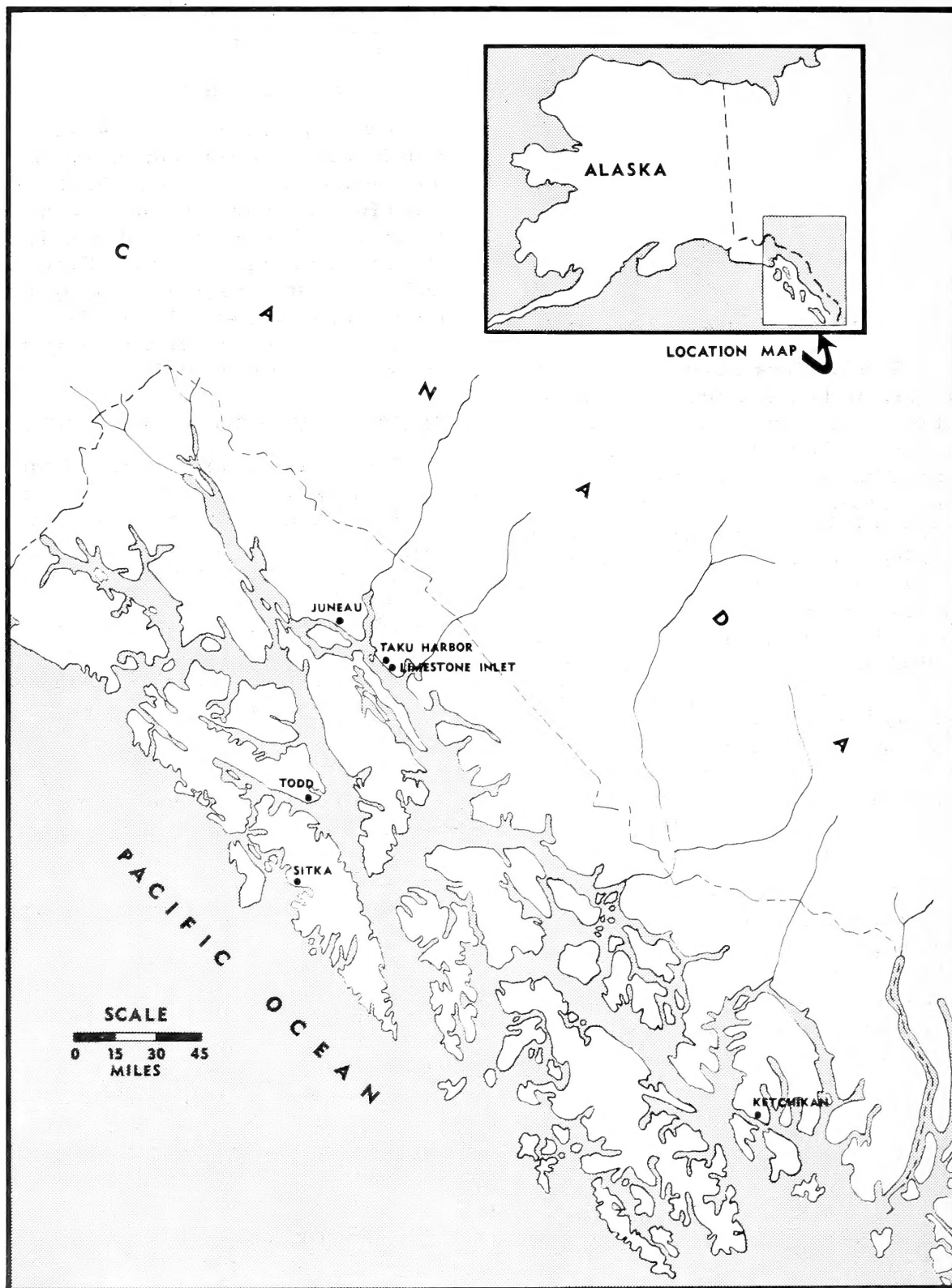


Figure 1.—Southeast Alaska.

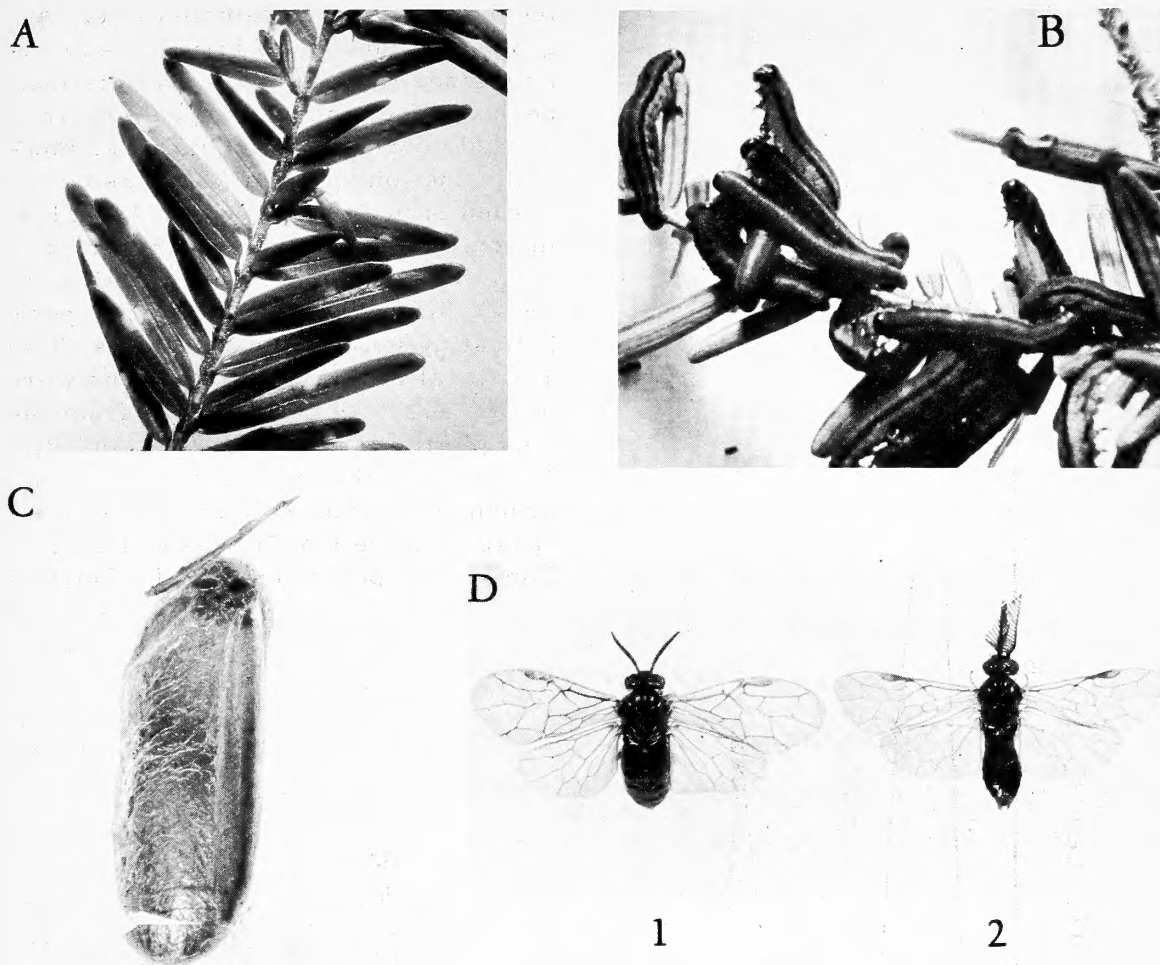


Figure 2.—Hemlock sawfly: A, Eggs on foliage; B, feeding larvae; C, cocoon; D, adults—(1) female and (2) male.

Although only one generation occurs annually, larvae of various sizes can be found from late June through August.

When adult females emerge, most of their eggs are mature, and mating occurs immediately. Of 81 captive females, some began ovipositing on the day of emergence, but others did not deposit eggs for several days. A mean of 3.4 days occurred from emergence to oviposition with a maximum of 12 days. Females deposit eggs singly in slits cut in the edge of needles, usually one egg per needle.

Hopping and Leech<sup>2/</sup> and Furniss and Dowden<sup>3/</sup> state that both sexes of larvae have five feeding instars. Our studies indicate that males have four

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<sup>2/</sup>Hopping, G. R., and Leech, H. B. Sawfly biologies I. *Neodiprion tsugae* Middleton. Can. Entomol. 68(4): 71-79. 1936.

<sup>3/</sup>Furniss, R. L., and Dowden, P. B. Western hemlock sawfly, *Neodiprion tsugae* Middleton, and its parasites in Oregon. J. Econ. Entomol. 34(1): 46-52. 1941.

feeding instars and females five. A graph of frequency of larval head capsule sizes (fig. 3) shows five distinct peaks. When these five peaks were plotted over date of occurrence, however, the fourth and fifth peaks occurred simultaneously (fig. 4). This indicates four feeding instars for each sex, the fourth peak representing fourth-instar males and the fifth peak indicating fourth-instar females. Two additional late larval collections were made, and head capsule size frequencies plotted by sex (fig. 5, A and B). The male peaks, which include a few prepupal larvae, coincide in size range with the fourth peak of figure 3. The female peaks overlap the fourth

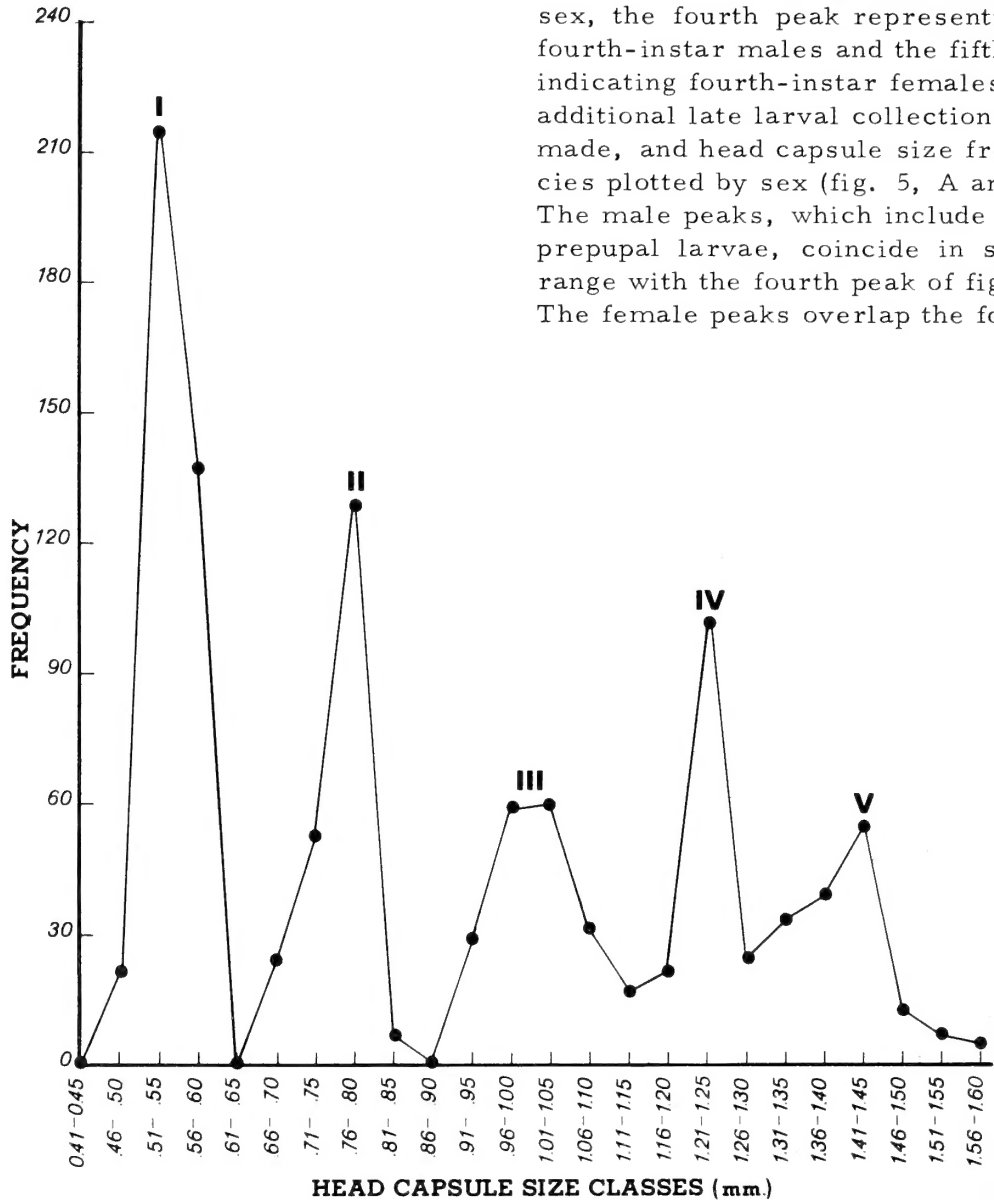


Figure 3.—Hemlock sawfly larval head capsule sizes (1,083 larvae), Limestone Inlet, 1961.



peak of figure 3, but the greatest frequency of females falls within the fifth peak of figure 3. This suggests that there are only four male sawfly feeding instars and five female feeding instars. The fourth peak of figure 3 is apparently composed of both sexes, and the fifth peak only females.

### LARVAL SEXING

Larvae were sexed by slitting the integument of the fifth abdominal segment laterally and exposing one of the gonads (fig. 6). Female gonads were almost invariably smaller than male gonads.

### LARVAL FEEDING

To determine needle consumption per larva and to compare survival of solitary versus group-reared larvae, we reared sawfly larvae on hemlock foliage in a field laboratory approximating field temperature and humidities.<sup>4/</sup> Forty-one larvae reared singly consumed an average of  $79.98 \text{ SE} \pm 44.70$  needles per larva and 414 larvae group-reared in 42

<sup>4/</sup> Werner, R. A. Feeding and oviposition behavior of the hemlock sawfly. Unpublished progress report, Northern Forest Exp. Sta., Juneau, Alaska. 1964.

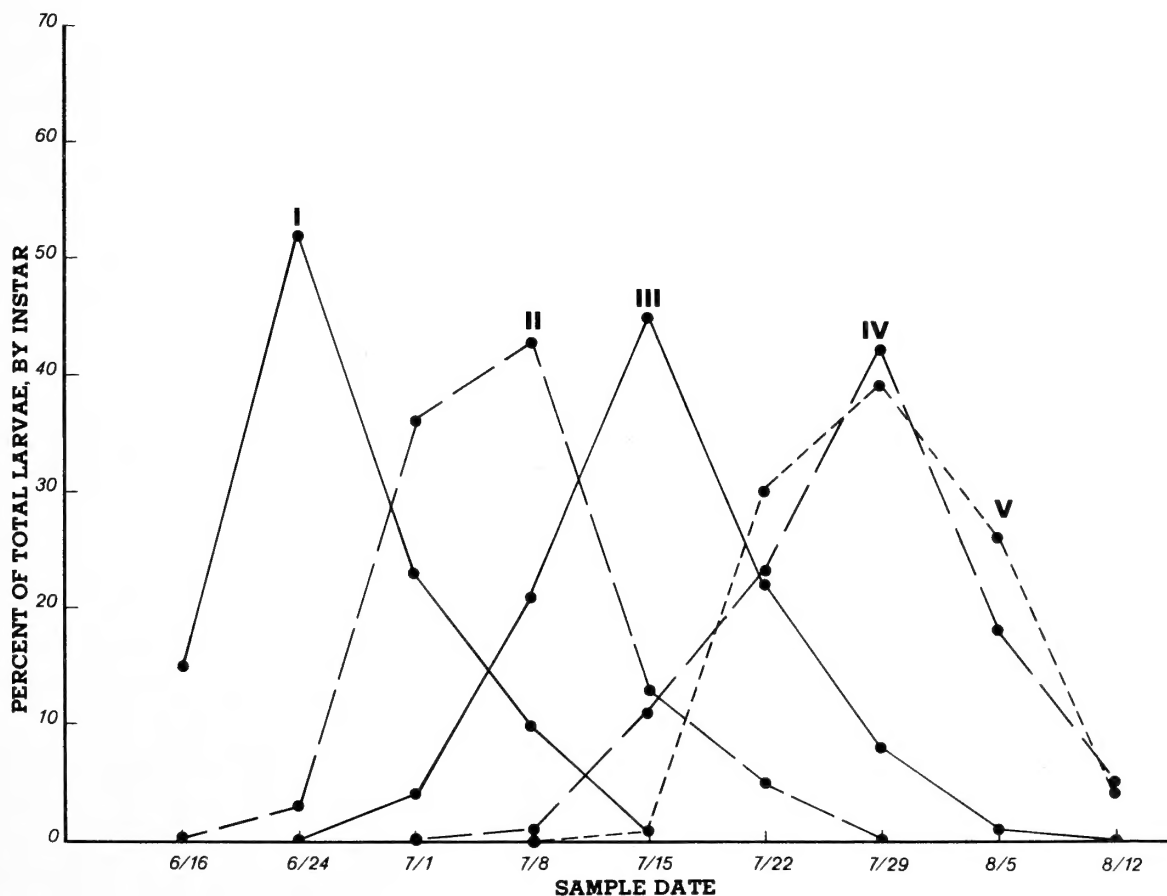


Figure 4.—Hemlock sawfly larval instar composition, Limestone Inlet, 1964.

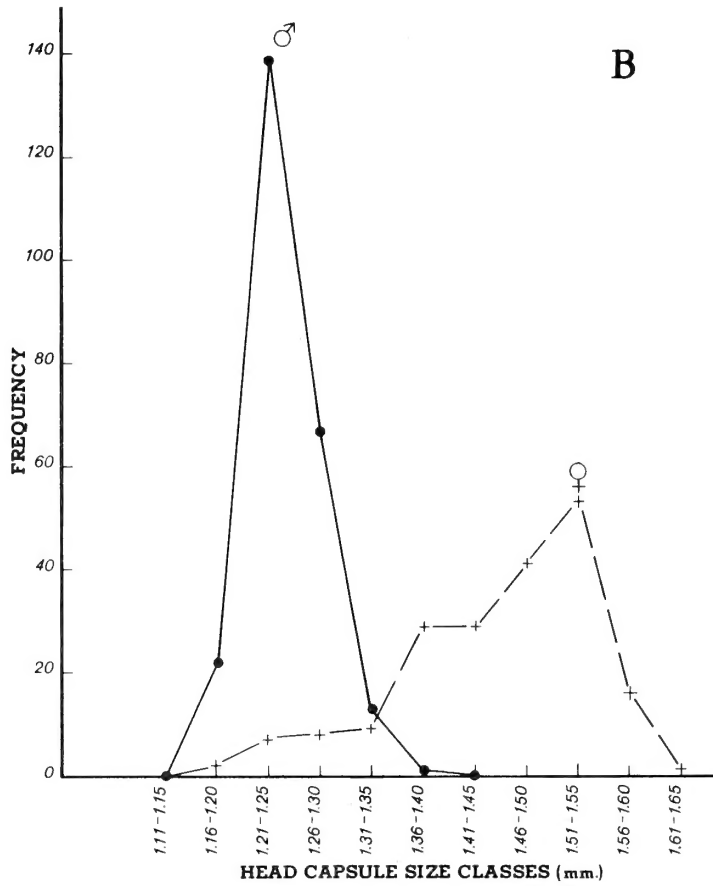
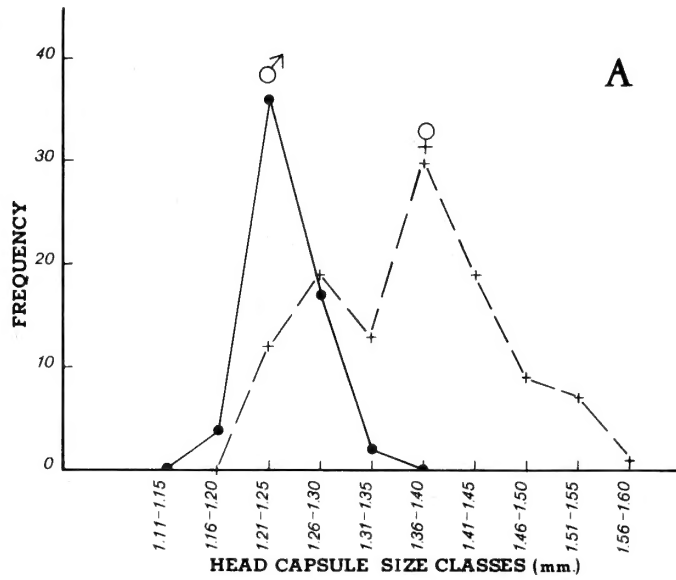


Figure 5.—A, Hemlock sawfly larval head capsule sizes by sex (169 larvae), Trap Bay, July 25, 1966; B, hemlock sawfly larval head capsule sizes by sex (439 larvae), Crab Bay, July 25, 1966.

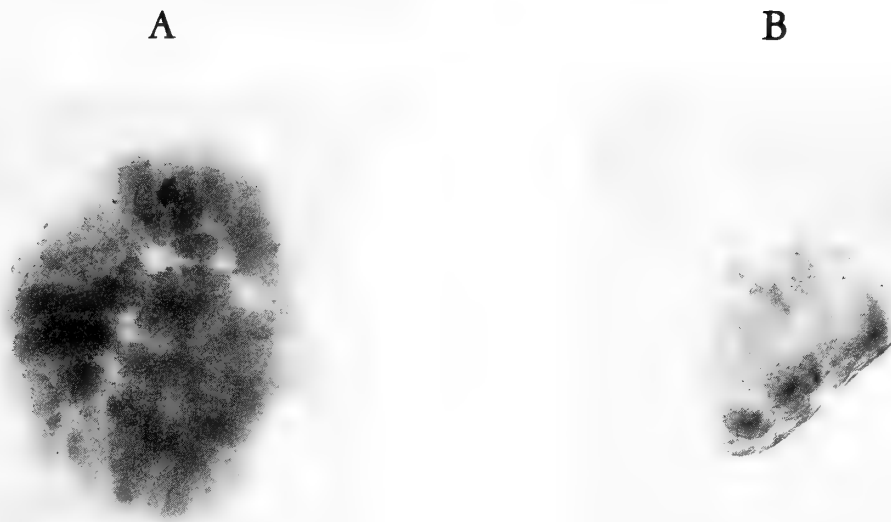


Figure 6.—Hemlock sawfly mature larval gonads; *A*, male; *B*, female.

cages consumed an average of  $82.38 \text{ SE} \pm 13.74$  needles per larva. An *F* test showed no significant difference at the 5-percent level between single and group-reared larvae in needle consumption per individual. In addition, a chi-square test indicated no significant difference in percent survival between single and group-reared larvae. Therefore, group feeding has no apparent survival value over solitary feeding. Incidence of parasitization or predation of sawfly larvae could vary under the two types of feeding conditions, however.

#### COCOON SIZE RELATED TO SEX

Cocoon measurements indicate that size is a fairly reliable means of sexing sawflies within the cocoons. One hundred and fifty male cocoons had a mean length of  $7.01 \text{ SD} \pm 0.29$

mm. and a mean width of  $2.65 \text{ SD} \pm 0.16$  mm. (fig. 7, *A* and *B*). There was no overlap of male and female cocoon lengths within a range of two standard deviations. Therefore, more than 95 percent of the cocoon population could be sexed by measuring the length. This technique provides a useful tool for determining sex ratio of a field population prior to adult emergence. Comparing sex ratios of cocoons and emerging adults could reveal differential mortality of the sexes while in the cocoons.

#### FECUNDITY

In order to determine the reproductive potential of the sawfly, we allowed 81 females collected in the field as cocoons to oviposit. We then dissected them to determine the number of remaining mature eggs. The mean number of laid and unlaid eggs

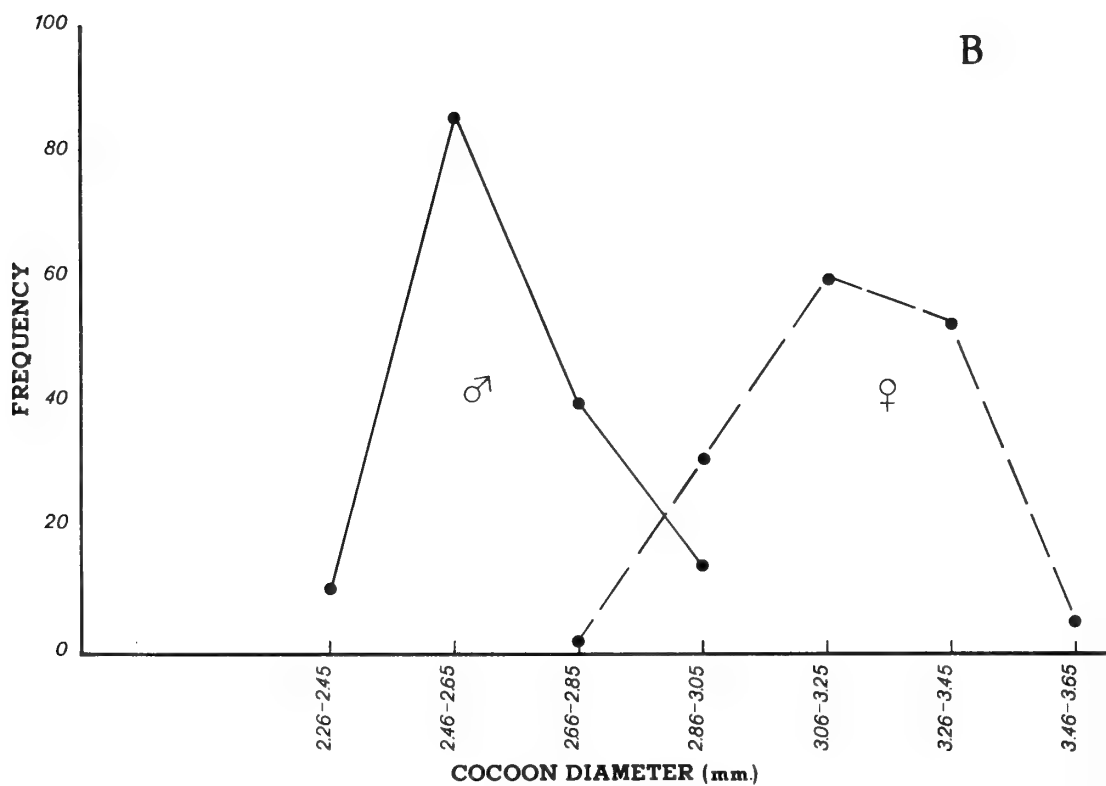
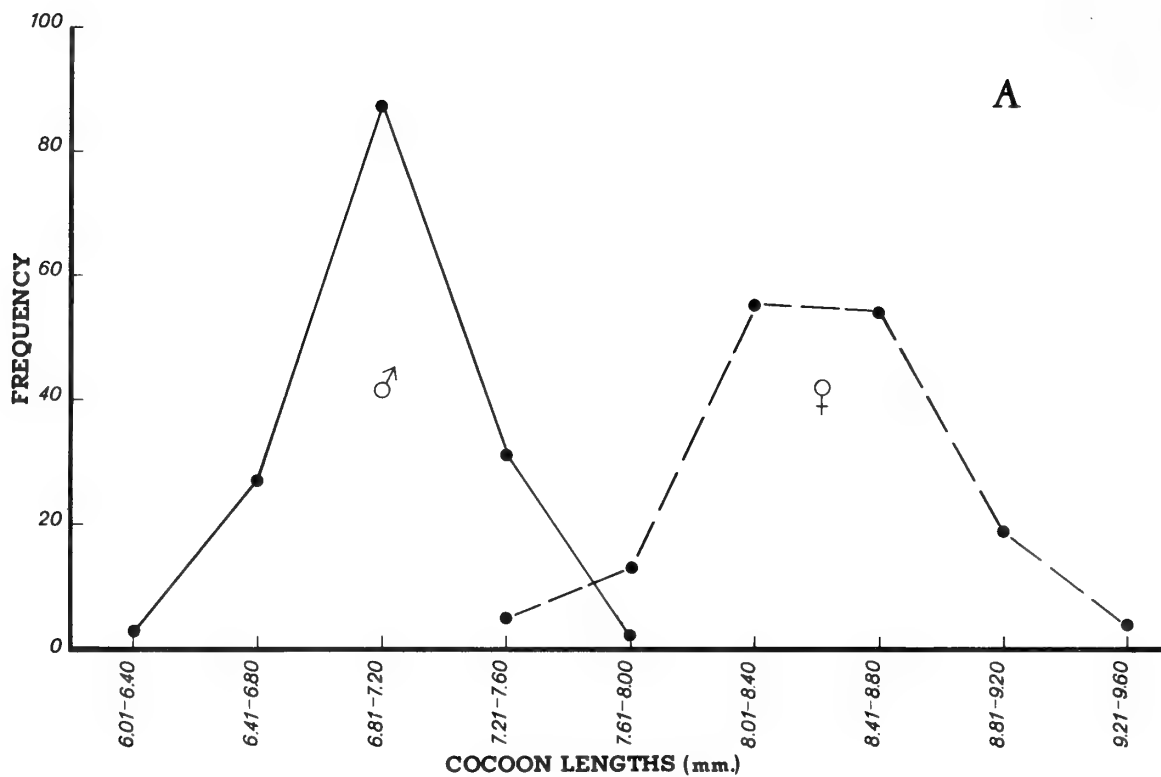


Figure 7.—A, Hemlock sawfly cocoon lengths by sex, Taku Harbor, 1963;  
B, hemlock sawfly cocoon diameters by sex, Taku Harbor, 1963.

for each female was  $72.3 \text{ SE } \pm 1.9$ . Maximum range was 20 to 112. Hopping and Leech<sup>5/</sup> dissected 10 females and determined a mean of 72.5 developed eggs. Range was from 61 to 103 eggs. Although fecundity varies with general health of individuals, it appears that approximately 72 eggs is close to the mean for a healthy hemlock sawfly population.

#### OVIPOSITION HABITS AND EGG DISTRIBUTION

Downing<sup>6/</sup> and Furniss and Dowden<sup>7/</sup> state that sawflies oviposit only on the current year's needles. We have observed eggs on both current and older foliage in the field, but oviposition predominated on the new foliage. A laboratory test of 24 ovipositing females showed no significant difference in egg deposition on current versus older foliage. A total of 117 eggs was laid on 176.6 linear inches of current year's foliage, and 121 eggs were laid on 173.3 linear inches of older foliage. The test was conducted in complete darkness to eliminate phototropic responses by the sawflies, and foliage was oriented horizontally to eliminate effects of geotropism. This test indicates that either phototropic or geotropic responses, or both, are responsible for heavier egg deposition on current foliage in the field.

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<sup>5/</sup> See footnote 2.

<sup>6/</sup> Downing, George L. Hemlock sawfly. U.S. Dep. Agr. Forest Pest Leaflet. 31. February 1959.

<sup>7/</sup> See footnote 3.

In heavy sawfly infestations, two or more eggs may be deposited in a single needle. A chi-square test of 246 egg-bearing needles was made to determine whether a significant difference in oviposition occurred on distal versus proximal edges of needles (distal edges are the needle edges facing the shoot tip; proximal edges face the base of the shoot). Significantly more eggs (140) occurred on the proximal edges.

An additional chi-square test was made of 272 egg-bearing needles to determine whether a significant difference in oviposition occurred on apical versus basal halves of needles. Most eggs (234) occurred on the apical halves.

Upper and lower crowns of 126 hemlock trees in seven stands were sampled to determine sawfly egg distribution. Analysis of variance showed that there were no significant differences in egg deposition (1) between intermediate and dominant or codominant trees; (2) among fringe trees on the beach, trees inside the fringe, and trees up the slope to 500 feet; or (3) among 10-inch, 18-inch, and 36-inch branch-tip samples. There were significant differences in oviposition between upper and lower crowns in moderate to high egg-population levels, however. Almost twice as many eggs were laid on upper crown samples as on lower crown samples. This was not true at low population levels.

Laboratory tests of over 100 females were made at 59° F., 75-percent relative humidity, and in complete darkness or at 90 foot-candles light intensity to determine factors



affecting oviposition. Egg counts showed that the ovipositing females were positively phototropic and negatively geotropic. This accounts, in part, for heavier egg deposition in upper tree crowns in the field. However, additional tests showed that females preferred to lay eggs on lower crown foliage as compared to upper crown foliage from the same trees. This preference overpowered phototropic and geotropic effects in the laboratory. Different environmental conditions such as greater light intensities that occur in the field could alter this preference. Whether the foliage preference is determined chemically or physically is unknown.

#### NATURAL CONTROL

Parasites. --Sawfly cocoons collected from foliage and litter in southeast Alaska yielded the following primary Ichneumonid parasites: *Opidnus tsugae tsugae* (Cushman), *Delomerista japonica diprionis* Cushman, *Itoplectis quadricingulatus* (Provancher), *Lamachus* spp., *Mastrus* spp., *Scambus* (*Scambus*) *nucum* (Ratzeburg), *Diadegma* sp., and *Rhorus* sp. *O. tsugae tsugae* accounted for more than half of the parasitized cocoons.<sup>8/</sup> Total parasitism varied from 3 to 40 percent. No parasites have been collected from sawfly larvae or eggs.

Diseases. --Fungus diseases caused almost complete larval sawfly mortality at Limestone Inlet in 1964 and at Todd in 1967. The insects

collected at Todd in 1967 were filled with resting spores of an entomophthorales fungus. Cool, moist conditions in southeast Alaska are favorable for fungi. No bacterial or virus diseases have been found in Alaska sawfly populations.

Other. --During the period of study, weather and predators did not cause noticeable sawfly mortality. However, mechanical injury and resultant drying of egg-bearing hemlock needles caused up to 34-percent overwintering sawfly egg mortality.<sup>9/</sup>

#### SUMMARY

1. There is one generation of the hemlock sawfly each year, and the winter is spent as eggs.

2. There is some evidence showing that males undergo four feeding instars and females five.

3. Although young larvae are normally gregarious, some are solitary, and laboratory studies showed that single larvae survived as well as those reared in colonies.

4. Most pupae can be sexed based on cocoon size since there was no overlap of male and female cocoon lengths within a range of two standard deviations.

5. Females produced an average of 72 eggs.

6. Field collections of eggs showed that nearly twice as many eggs were laid per square foot on upper

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<sup>8/</sup> Torgerson, Torolf R. Parasites of the hemlock sawfly, *Neodiprion tsugae* (Hymenoptera: Diprionidae), in coastal Alaska. (Ann. Entomol. Soc. Amer., in press.)

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<sup>9/</sup> Schmiede, D. C. Mortality of overwintering eggs of the black-headed budworm and hemlock sawfly in southeast Alaska. U.S. Forest Serv. Res. Note NOR-15. 1966.

tree crown samples as on lower crown samples at moderate to high egg-population levels.

7. Laboratory studies indicated that ovipositing females are positively phototropic and negatively geotropic. Despite this, and contrary to egg distribution in the field, foliage from lower crown areas was preferred over that of upper crowns.

8. Eight primary parasites have been collected from this sawfly. Fungus diseases may be responsible for sharp population declines, but adverse weather and predation have not been important control factors.



Hard, J. S., and Schmiede, D. C.

1968. The hemlock sawfly in southeast Alaska.

U.S.D.A. Forest Serv. Res. Pap. PNW-65, 11 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

The hemlock sawfly has one generation per year and overwinters in the egg stage. There are apparently four feeding male larval instars and five female instars. Cocoon measurements provide a fairly reliable means of sexing sawfly pupae. Females produce an average of 72 eggs. Parasites and a fungus disease are the most important natural control factors.

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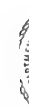
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